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GEOLOGY OF BURRUEL RIDGE

NORTHWESTERN SANTA ANA MOUNTAINS, CALIFORNIA

By JAMES F. RICHMOND

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NORTHWESTERN SANTA ANA MOUNTAINS, CALIFORNIA *

By James F. Richmond **

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ABSTRACT

On Burruel Ridge, in the northwestern Santa Ana Mountains, Orange County, a thick section of Tertiary sediments is exposed in a northwest-dipping homocline. The oldest sediments are Eocene, overlain successively by beds of the Sespe-Vaqueros (Oligocene-lower Miocene), Topanga (middle Miocene), Puente (upper Miocene), Repetto (?) (Pliocene), and La Habra (?) (probably Pleistocene) formations. The maximum exposed thickness is about 10,000 feet. The sediments are chiefly clastic, ranging in texture from conglomerate to shale, but there are also lenses of diatomite and volcanic rock. Rather extensive Quaternary terrace deposits are found above the present Santa Ana River and Santiago Creek.

The homocline is cut by several faults and in the eastern part of the area east-west structures are complicated by smaller north-south folds. An angular unconformity exists between the middle Miocene Topanga formation and the upper Miocene Puente formation; the Miocene-Pliocene contact may be gradational. Another unconformity occurs between the Pliocene and Pleistocene beds.

Local clay deposits have been used for making brick and sewer pipe near the town of Olive, and the upper Miocene diatomite beds may have commercial possibilities. Chief economic interest in the geology of the region is in its bearing on prospecting for petroleum.

INTRODUCTION

Geography. Burruel Ridge, shaped like a rude arrowhead with its point to the west, is the northwesternmost part of the Santa Ana Mountains of southern California. It lies south and east of the Santa Ana River and north of Santiago Creek, about 30 miles southeast of Los Angeles. The town of Olive at the point of the arrowhead has an elevation of 300 feet; eastward the ridge rises gradually to a crest of 3,045 feet at Sierra Peak about 12 miles away.

The present study is limited to the 15 square miles of the ridge in the Orange quadrangle. The area may best be reached from the north by a road through the Wagon Wheel ranch headquarters about 3½ miles east of Olive just south of Highway 18. Many smaller roads within the ranch boundaries give easy access to various parts of the area.

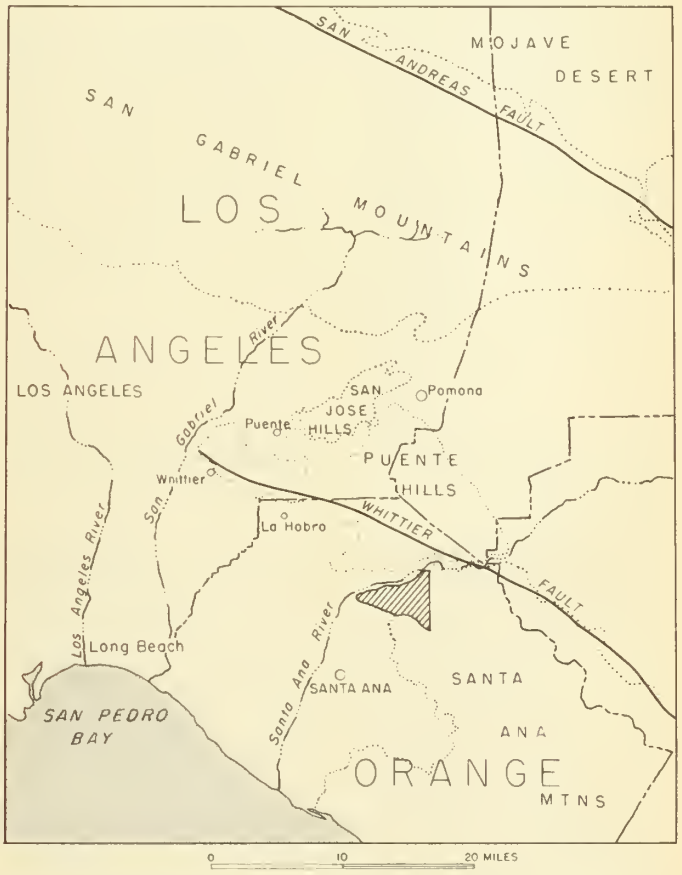

Figure 1. Index map showing location of Burruel Ridge area.

* Thesis prepared in partial fulfillment of the requirements for the degree of Master of Arts, Pomona College, 1950.
** Instructor in geology, Muir Junior College, Pasadena, California.

Climate and Vegetation. A mild semi-arid climate prevails. The winter temperature is rarely below 32° F., the summer rarely above 95° F. Rainfall averages about 15 inches per year at the Wagon Wheel ranch. A rather gentle north-dipping slope of the ridge supports good grass which reaches a maximum height of 30 inches in March or April. *Baccharis viminea*, a willow-like blossoming shrub sometimes 10 feet tall, grows in the steep V-shaped north-draining canyons. There, too, the common elderberry (*Sambucus glauca*) may reach 12 feet in height. The sandstone outcrops in particular support sage brush, including *Artemesia californica* (common sage brush), *Salvia mellifera* (black sage), and *Salvia apiana* (white sage). Common scrub oak (*Quercus dumosa*) grows to a height of 10 feet in the canyons and on sandy hillsides. The tallest member of the flora is a 15-foot shrub, the California holly (*Photinia arbutifolia*), which is often found in isolated stream-terrace remnants on the slopes of canyons. Many kinds of cactus thrive on the steep south slope.

Methods of Study. Field mapping was begun in August 1949, and continued through the fall and winter of 1949-50 as time allowed. Field data were accumulated on aerial photographs flown by Fairchild Aerial Surveys, Inc., at the scale of 1 inch equals 1200 feet, or 1 : 14,000.

Previous Work. Although a number of oil companies have done geologic work on Burruel Ridge, very little has been published about the area.

Mendenhall [1] has published in Water-Supply Paper 137 a map (scale 1:250,000) showing artesian areas and hydrographic contours in the "valley of Southern California," and a topographic map (scale 1 : 62,500, contour interval 25 feet) showing irrigated lands. In the same report he included many tables of data on water wells.

McLaughlin and Waring [2] discussed the general structure of the oil producing areas of California and stated that on Burruel Ridge "an anticline with axis running N. 70° W. passes through the point," and that Santiago Creek possibly follows the foot of a fault scarp, "the north being the upthrust side."

Dating of some of the lithologic units described by English [3] has been modified in the light of subsequent work with microfauna. His work remains today the only publication dealing with the Puente formation as a whole, and the only work devoting attention to the geology of Burruel Ridge. His map, scale 1:62,500, is the largest available for the area.

Eckis [4] investigated water resources. He included with his South Coastal Basin investigation a geologic map (scale about 1 : 145,000) of the "South coastal plain and adjacent areas" on which Burruel Ridge appeared. He did not differentiate the Puente formation, but did divide the Pliocene beds into water-bearing and non-water-bearing facies, and stated that the latter is probably a correlative of the Pico and Repetto formations.

[1] Mendenhall, W. C., Development of groundwater in the eastern coastal region of California: U. S. Geol. Survey Water-Supply Paper 137, 1905.

[2] McLaughlin, R. P., and Waring, C. A., Petroleum industry of California: California Min. Bur. Bull. 69, pp. 305-367, 1914. (No map; some structure sections. See p. 364.)

[3] English, W. A., Geology and oil resources of the Puente Hills region, southern California: U. S. Geol. Survey Bull. 768, 1926. (Map and structure sections.)

[4] Eckis, Rollin, Geology and ground water storage capacity of valley fill: California Div. Water Res., South Coastal Basin Investigation, Bull. 45, 1934.

Eldridge and Arnold [5] furnished the first published definition of the Puente formation of upper Miocene age. They defined the upper shale, sandstone, and lower shale members.

Krueger [6] suggested the name Sycamore Canyon formation for a thick sedimentary unit of upper Miocene age which had previously been considered Pliocene.

Daviess and Woodford [7] in their study of northwestern Puente Hills retained the three units of Eldridge; they added Krueger's Sycamore Canyon formation as the uppermost member of the Puente formation.

Acknowledgments. A. O. Woodford gave generous assistance with the petrographic and stratigraphic problems which arose in the course of this work. D. M. Kinney and J. E. Schoellhamer of the U. S. Geological Survey made valuable suggestions for field procedure. Thomas Rothwell and Manley L. Natland of Richfield Oil Corporation made the microfaunal identifications and age determinations. John Forman, Frank Goodban, and Willis Burnham of Pomona College assisted in the measurement of sections and in the identification of megafossils. Several oil companies generously granted permission to publish subsurface information obtained from wells drilled for oil. Shell Oil Company furnished financial aid in the form of a fellowship.

STRATIGRAPHY AND PALEONTOLOGY

Santiago Formation

The oldest sediments cropping out on Burruel Ridge are exposed in the southeastern corner of the area. Typically, the beds consist of coarse buff-colored sand, and a few thin pebble beds which do not ordinarily persist for more than 50 feet along the strike. J. G. Vedder,[8] from whose map the Santiago-Sespe contact was taken, believes that these non-fossiliferous, apparently nonmarine sediments are to be correlated with the upper Eocene Santiago formation described by Woodring and Popenoe.[9]

Sespe and Vaqueros Formations Undifferentiated

A red or white conglomeratic sandstone overlies the Santiago formation. This is the basal member of a formation of variable thickness, color, and composition. The maximum exposed thickness of the formation is about 3,000 feet, and the whole is characterized by a deep red color. This is especially true of the top of the formation on Burruel Ridge, where the contact with the overlying light-gray to buff Topanga formation is sharply marked. Following the precedent of English,[10] the beds marked at the top by this distinctive red lithology have been assigned to the Sespe and Vaqueros formations of Oligocene

[5] Eldridge, G. H., and Arnold, Ralph, The Santa Clara, Los Angeles, and Puente Hills oilfields: U. S. Geol. Survey Bull. 309, pp. 103-105, 1907.

[6] Krueger, M. L., The Sycamore Canyon formation, California (abstract): Am. Assoc. Petroleum Geologists Bull., vol. 20, p. 1520, 1936.

[7] Daviess, S. N., and Woodford, A. O., Geology and structure of the northwestern Puente Hills, California: U. S. Geol. Survey, Oil and Gas Investigations, Prelim. Map. 83, 1949.

[8] Vedder, J. G., The Eocene and Paleocene of the northwest Santa Ana Mountains: unpublished M.A. thesis, Claremont College, 1950.

[9] Woodring, W. P., and Popenoe, W. P., Paleocene and Eocene stratigraphy of northwestern Santa Ana Mountains, Orange County, California: U. S. Geol. Survey, Oil and Gas Investigations, Prelim. Chart 12, 1945.

[10] English, W. A., Geology and oil resources of the Puente Hills region, southern California: U. S. Geol. Survey Bull. 768, 1926.

Table 1. Generalized stratigraphy of Burruel Ridge.

Age	Geologic formation	Description	Approximate thickness
Recent	Alluvium	Poorly sorted unconsolidated gravel, sand, and clay.	50
Pleistocene	Terrace deposits	Old stream deposits, somewhat dissected.	75
		———Unconformity———	
	La Habra (?)	Poorly consolidated, somewhat deformed continental conglomerate, sand, and siltstone.	250
		———Unconformity———	
Lower (?) Pliocene	Repetto (?)	Brown and blue siltstone, sandy shale and sandstone; thin conglomerate members.	900
Upper Miocene	Puente	Alternating marine shale and sandstone members. Sharp local variations. Local unconformity between upper sandstone and upper shale members.	3,000
		———Unconformity———	
Middle Miocene	Topanga	Massive gray and brown marine sandstone and thin conglomerate with local siltstone. Extrusive (?) diabase and tuff at or near top.	1,200
Lower Miocene-Oligocene	Vaqueros-Sespe	Undifferentiated coarse red and brown conglomerate and sandstone.	2,500
Eocene	Santiago	Coarse sandstone with thin local conglomerate.	800

and lower Miocene age. No fossils were found in reconnaissance mapping of the formation; therefore the Vaqueros formation containing lower Miocene *Turritella inezana* is probably locally missing. The red beds at the upper contact range along the strike from soft red clayey sand to pebble conglomerate.

Topanga Formation

Above the Vaqueros-Sespe sediments is a coarse-grained, arkosic sandstone which has an average thickness of about 900 feet. The predominant sandstone of the formation ranges from a soft white, massive arkose, tending to form saddles or gently rounded contours, to a hard, buff-colored quartzose sand, cropping out in resistant ledges which furnish excellent marker beds along the rever-slope south of the ridge. Some thin interbedded conglomerate, siltstone, and limestone occur in this commonly well-bedded formation. The conglomerate beds are notable for their relatively uniform thinness, granule to pebble size, and for the prominence in them of angular dark schist fragments similar to the slightly metamorphosed Triassic(?) basement rocks in the Santa Ana Mountains to the southeast. The siltstone is soft and non-persistent, and most of it occurs as short beds or lenses up to 150 feet in thickness. Thin limestones are interbedded in places with the siltstones.

Where the Topanga formation enters Burruel Ridge from the southwest it is overlain by a conglomerate of well-rounded cobbles, which contains a high percentage of purple volcanic clasts. To the east a thin layer of fine-grained yellow tuff, weathering to clay, marks the upper contact. At the contact with the overlying lower Puente formation along section CC′ (see pl. 1), there is a thin outcrop of igneous rock. Near the contact at section DD′ there are two outcrops of fine-grained yellow-brown andesite tuff at the top of the formation. From that point eastward a tongue of fine-grained sandstone, which thickens toward the east, separates two shale members. The contact with the overlying Puente formation was placed at the base of the upper shale unit, but the base of the lower shale unit may be the proper contact.

Marine fossils were found in several zones in the Topanga formation. Although these zones typically contain remarkably few species and are less than 6 feet thick, they may persist laterally for some distance. About 150 feet above the base of the formation casts of *Chione temblorensis(?)* were found at two localities (14 and 15 on pl. 1). From 300 to 500 feet above the base a persistent fossil bed, composed of at least 95 percent *Turritella ocoyana*, is traceable for about a mile and a half along the strike ("T.O." line on pl. 1). About 50 feet above the *Turritella ocoyana* zone, a few casts of a small *Arca* occur.

Foraminifera of the genera *Bolivina* and *Valvulineria*, too badly weathered for specific identification, were collected from one of the thin limestone beds just west of section CC′ (pl. 1).

Puente Formation

As defined by Eldridge,[11] the Puente formation, named for its principal area of outcrop in the Puente Hills, included three members: an upper shale, a sandstone, and a lower shale. The varied lithology of each of the members was recognized by Eldridge and Arnold, but the need for subdivisions to facilitate field mapping led to arbitrary adoption, and later widespread recognition and acceptance, of the three chosen members.

English[12] subsequently proposed that the Puente formation on Burruel Ridge be subdivided into four units:

> Throughout the Puente Hills the lower division of the Puente formation consists of a single shale unit, but in Burruel Ridge a sandstone divides this shale into a lower and an upper part. It is only in the Santa Ana Mountains that the base of the lower division is exposed and there it appears to rest unconformably on Topanga sandstone. . . . On Burruel Ridge there is a lower shale separated from the main shale zone by several hundred feet of yellow sandstone similar to that found in the underlying Topanga. This sandstone is mapped as a lentil in

[11] Eldridge, G. H., and Arnold, R., The Santa Clara, Los Angeles, and Puente Hills oilfields: U. S. Geol. Survey Bull. 309, 1907.
[12] English, W. A., Op. cit., pp. 33-34.

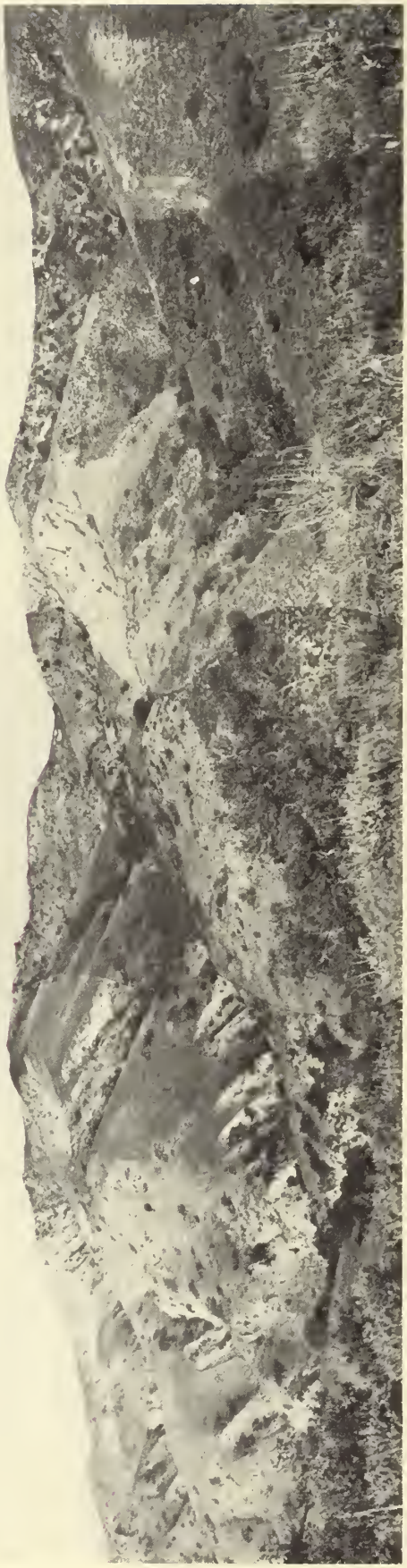

FIGURE 2. Typical exposure of Topanga formation (left); the conformably overlying lower Puente shale is well exposed on hill at extreme right of photo. View west to northwest from Hill 1152.

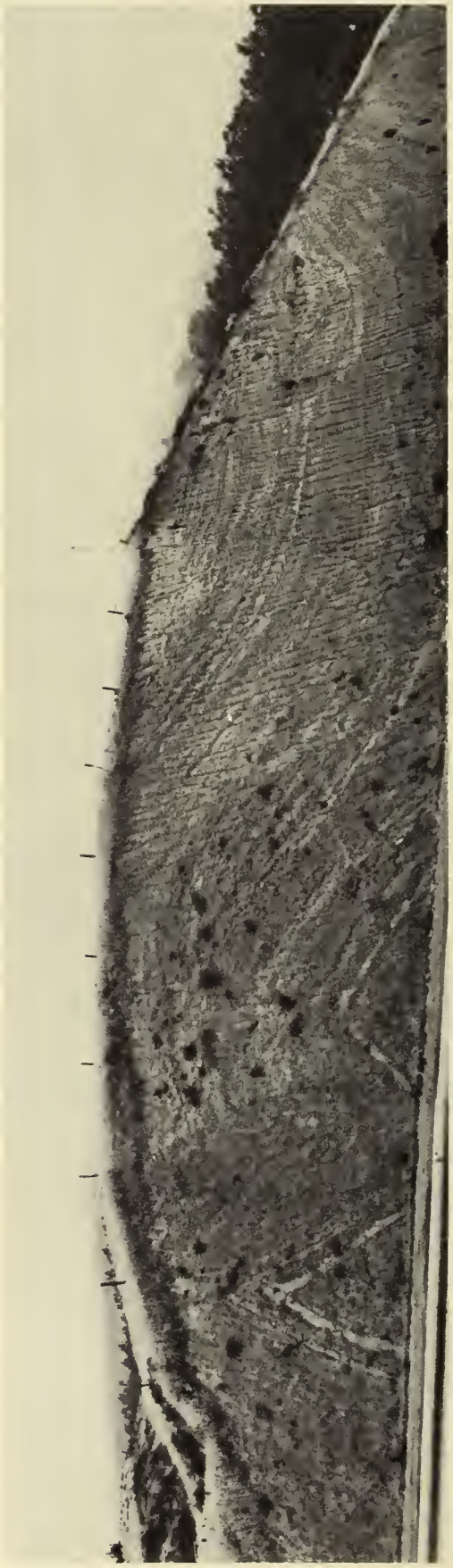

FIGURE 3. Structures in road cut at Burruel Point. View west to northwest.

the shale. . . . It is uncertain whether the base of the lower or of the upper of the two shale zones is to be correlated with the base of the shale as mapped over the area south of Santiago Canyon and in the Puente Hills.

Thus on Burruel Ridge the three lower units chosen by English correspond to the single lower unit of Eldridge. English mapped the uppermost Miocene sand unit on Burruel Ridge as the equivalent of the middle sandstone unit described by Eldridge. English considered Eldridge's upper unit, the upper shale member of the Puente formation, to be locally missing.

The foraminiferal evidence at present available poses problems in nomenclature similar to those encountered by others who have worked in the Puente formation. The lower shale unit to which English refers in the above quotation, is indicated by microfauna to be lower Mohnian in age and therefore, following present usage, to belong properly to the lower shale member of the Puente formation. English assigned it doubtfully to this formation. The microfaunal evidence available from the shale above the yellow sandstone mapped by English as a "lentil in the shale" suggests an upper Mohnian age. Should this prove generally to be true, the age of the "lentil in the shale" is fairly well established. But the upper sandstone, mapped by English as middle Puente sandstone, must be younger than the upper Mohnian shale upon which it lies.

In the western Puente Hills Krueger [13] suggested the name Sycamore Canyon formation for a 3,800-foot interval of alternating conglomerate, sand, siltstone, and shale previously described as part of the Fernando formation (Pliocene). In the Puente Hills this formation is overlain by the Repetto (lower Pliocene) and is "unconformably superjacent" to the upper Puente member of the Puente formation; but both the Puente formation and the Sycamore Canyon formation contain upper Miocene microfaunas.

[13] Krueger, M. L., The Sycamore Canyon formation, California (abstract): Am. Assoc. Petroleum Geologists Bull., vol. 20, p. 1520, 1936.

FIGURE 4. View N. 55° E. from crest of Burruel Ridge toward Wagon Wheel ranch buildings (left). Light-colored upper Puente shale (grass-covered) dips northwest beneath darker Sycamore Canyon sandstone (brush-covered). Puente Hills in the distance.

Daviess and Woodford [14] used the term Sycamore Canyon to describe an upper Miocene conglomerate unit over 3,000 feet thick, which overlies the upper Puente siltstone in the northwestern Puente Hills. They recognized four members of the Puente formation: a lower siltstone member, a sandstone member, an upper siltstone member, and the Sycamore Canyon member. Thus the effect was to retain for the time being the generalized divisions proposed by Eldridge, with the addition of a new member at the top of the formation.

The member above the upper Puente shale on Burruel Ridge is a sandstone that contains thin pebble lenses and some cobbles. There is not—at least east of the Wagon Wheel house—any unconformity between it and the upper Puente shale such as Krueger [15] suggests is present in the Puente Hills. However, because the sandstone section on Burruel Ridge overlies shale of probable upper Mohnian age and in turn is overlain by the Repetto (?) formation, the name proposed by Daviess and Woodford, Sycamore Canyon member of the Puente formation, has been adopted for it.

Lower Puente Shale Member. The lower member of the Puente formation is called a shale, following the terminology of earlier workers in the area. Actually, the sandstone and siltstone interbedded with it are perhaps thicker than the shale. The unit lies on the Topanga sandstone and tuff with some angular unconformity. One good exposure is about a quarter of a mile east of the line of section CC′ (pl. 1), where the lower Puente member strikes N. 72° E. and dips 28° NW., while the Topanga formation trends N. 50° W. and dips 34° NE. In many places there is less angular discordance between the formations. Steeper north dips are typical of the Topanga formation.

The lower Puente member in the vicinity of Burruel Point is quite soft where the beds are locally overturned. Eastward it becomes a platy, porcelaneous shale which weathers out in cherty fragments or tabular blocks 4 or 5 inches long. Traces of bluish carbonaceous material are common on the weathered surfaces of these fragments, and traces of badly weathered foraminifera can often be found in float from the few thin limestone beds. Some large limestone concretions occur. The lower Puente shale contains one or more sandstone beds up to 10 feet thick, which, in their infrequent exposures, are found to be coarse-grained.

Most exposures of the lower Puente member are poor, especially those near the top of the member. The contact with the middle sandstone member is difficult to place, not only because of poor exposures, but because of its graduational nature.

The base of the formation is more clearly marked. In the west it is a white limestone breccia which contains many large cobbles of purple porphyritic volcanic rocks in a matrix of clear, shiny, very angular quartz clasts up to 5 millimeters in diameter, as well as some larger pieces of hard, dark-gray, fine-grained sandstone. Permeating the matrix is a white caliche-like cement which is somewhat punky and appears to be comparatively recent. To the east, hard porcelaneous beds near the base of the

[14] Daviess, S. N., and Woodford, A. O., Geology and structure of the northwestern Puente Hills, California: U. S. Geol. Survey Oil and Gas Investigations, Prelim. Map. 83, 1949.

[15] Krueger, Op. cit.

Table 2. Fossil locality index.

No. on map (pl. 1)	Field number	Principal fossils*	Formation	Age determination
1	241	Arca trilineata calcarea	Repetto	Pliocene
2	253	Arca trilineata calcarea	Repetto	Pliocene
3	202	Arca trilineata calcarea	Repetto	Pliocene
4	242	Arca multicostata Sowerby	Repetto	Pliocene
5	209	Foraminifera	Repetto	Pliocene
6	223	Foraminifera	Upper Puente	Mohnian
7	215	Foraminifera	Upper Puente	Mohnian
8	373	Foraminifera	Lower Puente	Mohnian
9	199	Foraminifera	Upper Puente	Mohnian
10	257	Foraminifera	Upper Puente	Mohnian
11	479	Foraminifera	Upper Puente	Mohnian
12	400	Fish scales	Lower Puente	Lower Mohnian
13	556	Fish scales	Upper Puente	Upper and Lower Mohnian
14	538	Chione temblorensis (?)	Topanga	Middle Miocene
15	444	Chione temblorensis (?)	Topanga	Middle Miocene
T.O.	Bed	Turritella ocoyana	Topanga	Middle Miocene

* Microfossil determinations by Thomas Rothwell and M. L. Natland of Richfield Oil Corporation.

member form strike ledges which protrude a few feet above the softer, sandier layers.

Like other members of the Puente formation the beds of the lower member thin and thicken rapidly. The maximum thickness of the lower Puente shale is about 600 feet.

One collection of foraminifera diagnostic only of Mohnian age was made from these beds near Burruel Point (loc. 8, pl. 1). It included *Bolivina decurtata?, Bolivina vaughani, Buliminella curta, Ellipsolagena* sp., *Globigerina bulloides, Pseudoparella subperuviana, Suggrunda* sp., *Valvulineria "pseudocalifornica,"* and *Virgulina californiensis* (not *grandis*). East of section CC′ (pl. 1) scales of *Etringus scintillans*, a lower Mohnian herring, were collected at locality 400 (loc. 12, pl. 1).

Middle Puente Sandstone Member. A massive white to yellow coarse-grained to conglomeratic arkosic sandstone lies conformably above the lower shale member. This is the yellow sandstone lentil described by English. The thickness of the unit changes with great rapidity as is indicated on the geologic map, but averages about 1,200 feet.

At Burruel Point the sandstone member contains two platy shale lenses each about 50 feet thick and similar to the underlying shale. These thin and disappear eastward within about a mile. Just east of section CC′ (pl. 1) there is an isolated patch of shale about 200 feet thick, mapped as the upper Puente member of the Puente formation, which is surrounded by middle Puente sandstone. Fish scales found in it (loc. 13, pl. 1), were identified by M. L. Natland as *Xyne grex,* an upper Mohnian herring; and *Etringus scintillans,* a lower Mohnian or lower-upper Mohnian herring. It is possible that this shale unit is a lens in the middle Puente sand, similar to lenses that occur to the west.

Near the top of the member a 25-foot bed of coarse gray sandstone overlying a thin, hard, calcareous shale is found between Burruel Point and the Wagon Wheel ranch house. East of Wagon Wheel ranch house the top of the formation is marked by numerous round or spindle-shaped concretions as much as 18 inches in diameter, and composed of coarse gritty sand. The main body of the formation coarsens eastward, and grades to a pebbly sandstone. The occasional thin non-persistent conglomerates, always poorly sorted, become coarser and more angular. Quartzite and coarse quartz-rich plutonites, and some large angular slabs of blue-gray schists, are the common constituents of the conglomerate.

The only fossils found in this member, not including the fish scales mentioned above, were two casts of a small unidentifiable clam.

Upper Puente Shale Member. The base of the upper Puente member is generally marked by several thin beds (as much as 15 inches in thickness) of gray-white dense limestone in coarse sand somewhat lighter in color than that of the underlying middle sandstone member. The contact between the middle Puente sandstone and the upper shale is gradational. Although the contact was mapped at the base of the lowest limestone bed, where it is well exposed in a cut just east of section AA′ (pl. 1), it is not likely that the same limestone bed persists either to the east or to the west. The contact was most easily traced, however, by means of these limestone beds.

Above the zone of interbedded sandstone and limestone are three other units which, when present, serve as useful stratigraphic guides. The lowest of these is a soft, punky diatomite deposit 300 or 400 feet thick, which crops out for about half a mile east and half a mile west of section AA′ (pl. 1). So fine-grained is this pink to white, finely laminated sediment that two samples, each about 500 cc, being examined for possible foraminifera, washed entirely through a 150-mesh sieve except for about $\frac{1}{5}$ cc of diatoms and sponge spicules. The diatomite bed was not found east of section BB′ (pl. 1).

Above the diatomite and cropping out more persistently, although intermittently, eastward is a rather hard, white to putty-colored pokerchip shale, in part diatomaceous and in part foraminiferal. Its maximum thickness is not more than 75 feet.

Above the gray-white pokerchip shale is a buff to pink silty sandstone. The bedding planes are poor and are replaced by a characteristic hackly fracture. Some fairly large exposures consist of tabular, shard-shaped fragments 2 or 3 inches long and so jointed that the bedding planes cannot be distinguished from the fracture. The hackly pink siltstone is the most persistent unit of the upper Puente shale. It thickens eastward at the expense of the middle units of the member, and east of the Wagon Wheel ranch house may have a maximum thickness of

FIGURE 5. Westernmost occurrence of concretions at base of Sycamore Canyon sandstone. View N. 10° E.

FIGURE 6. View N. 70° E. along contact of Sycamore Canyon sandstone (left) and upper Puente shale (right). The shale forms the row of hills on the right.

800 feet. Some short but thick lenses of coarse sandstone occur in the eastern exposures. Mudstone lenses are common.

Foraminifera were washed from several localities in the upper Puente shale. The locality of the collections and the determinations of the microfossils as given by Mr. Rothwell are listed below. All of the collections are Mohnian in age.

Locality 223 (loc. 6, pl. 1)—near base of upper Puente shale

Bolivina cf. decurtata
Bolivina tumida
Bolivina woodringi
Gyroidina sp.
Pseudoparella cf. capitanensis
Pseudoparella sp. of Kleinpell
Suggrunda sp.
Uvigerina sp. costati
Valvulineria araucana
Virgulina californiensis var. grandis

Locality 215 (loc. 7, pl. 1)—near middle of diatomite beds, middle of upper Puente shale

Bolivina bramlettei
Bolivina cf. decurtata
Bolivina vaughani (abund.)
Bolivina woodringi
Eponides cf. mansfieldi
Pseudoparella subperuviana
Suggrunda sp.

Locality 199 (loc. 9, pl. 1)—near base of upper Puente shale

Bolivina "decasata"
Bolivina decurata
Bolivina vaughani
Discorbinella valmonteensis
Eponides mansfieldi

Locality 257 (loc. 10, pl. 1)—from pokerchip shale unit, middle of upper Puente member

Bolivina decurtata
Bolivina cf. pseudospissa
Bolivina seminuda
Bolivina sinuata
Bolivina tongi
Bolivina woodringi
Buliminella curta
Buliminella elegantissima
Eponides mansfieldi
Eponides rosaformis
Eponides sp.
Globigerina bulloides
Nodosaria tympaniplectriformis
Nonion goudkoffi
Pseudoparella subperuviana
Valvulineria araucana
Uvigerina sp. (finely costate var. to hispid)

Locality 479 (loc. 11, pl. 1)—from clayey shale above hackly pink siltstone unit, upper part of upper Puente member

Angulogerina sp.
Bolivina decurtata
Bolivina girardensis
Bolivina tumida
Bolivina vaughani
Cassidulina subglobosa var. quadrata
Discorbinella valmonteensis
Globigerina bulloides
Gyroidina soldanii var. rotundimargo
Pseudoparella subperuviana
Uvigerina sp.
Uvigerina sp. (numerous fine costae, becoming costate)

In addition, several specimens from thin limestone beds containing on their surfaces partially weathered-out formainifera were examined by Mr. Rothwell, who found them to be a facies fauna not diagnostic of age. Typically these limestones contained *Pseudoglandulina* (large, cigar-shaped) and some or all of the following forms:

Bolivina woodringi (?)
Buliminella curta
Cassidulinoides cf. cornuta
Cheilostomellid (new genus?)
Gyroidina sp. (large, round)
Nodosaria sp. (trumpet-like aperture)
Nonionella sp. (large, inflated, coiled)
Pseudoglandulina sp.
Pseudoparella capitanensis

On the slope of Burruel Ridge east of section BB′ (pl. 1) some whale (?) vertebrae were found near the top of the hackly pink siltstone unit of the upper shale member.

Sycamore Canyon Member. The westernmost occurrence of the Sycamore Canyon sandstone has not been discovered, because of its similarity to the apparently conformable overlying Pliocene beds and its obscured contact with the upper Puente shale. Beginning midway between sections BB′ and CC′ (pl. 1), however, the base of the Sycamore Canyon sandstone is clearly marked by large, spindle-shaped concretions of coarse sandstone somewhat larger but less numerous than those at the top of the middle Puente sandstone east of the Wagon Wheel ranch. Concretions are found also about 250 feet and 600 feet above the base of the Sycamore Canyon sandstone; they become more numerous eastward. Above the concretions the sandstone is coarse, and in its westernmost occurrence, extremely soft and very micaceous. One sample studied microscopically was estimated to contain about 40 percent biotite, all of it fresh.

FIGURE 7. Dipping sandstone and pebble beds mapped as La Habra (?) formation.

Eastward, the Sycamore Canyon sandstone contains near the base a few thin, yellow, sandy limestone beds as well as some pebble conglomerate. Quartz fragments are here more abundant than mica and the sandstone is yellow and somewhat muddy. The pebbles are well sorted, fresh, and well rounded. A pebble-count showed 48 percent plutonic, 30 percent metamorphic, 9 percent sedimentary, and 12 percent volcanic rock types, all well rounded and between half an inch and an inch in length. The sandstone above the concretions has a tendency to form massive cliffs as much as 10 feet in height. Still higher in the member very thin-bedded, micaceous green shale commonly occurs interbedded with the sandstone at 10- or 12-inch intervals. The exposed maximum thickness of the Sycamore Canyon sandstone is not more than about 1,200 feet. It thickens rapidly from west to east.

Where the Sycamore Canyon sandstone enters the section in the west there may be a slight disconformity between it and the upper Puente shale. The contact west of Wagon Wheel ranch house may be slightly faulted just north of the low rounded hills so noticeably aligned along the strike; but the actual relationship is obscured by landslides. The underlying shales are here badly crumpled and dip very steeply, most of them to the north; but it is probable that this local crumpling has resulted from downslope creep of the incompetent beds against the more resistant Sycamore Canyon sandstone, rather than from movement on the hypothetical fault, along which no displacement is apparent.

The relationship of the Sycamore Canyon sandstone to the middle Puente sandstone in the east is not clear, although it was mapped as local overlap. The contact was taken at the base of a coarse-grained yellow conglomeratic sandstone which forms an abrupt cliff 10 or 15 feet high above the contact. Concretions of coarse sandstone also occur at intervals in the overlying sand.

No fossils were collected from the Sycamore Canyon member of the Puente formation. Because it lies between beds assigned to the lower Pliocene and upper Mohnian, its age seems most likely to be equivalent to the Delmontian stage.

Miocene-Pliocene Contact

English [16] and Adams [17] state that the Pliocene beds on Burruel Ridge unconformably overlie the Puente formation. English correlated the Pliocene beds with the Fernando group but did not differentiate the beds. Adams reported on foraminifera from three Pliocene localities he found above megafossils at Burruel Point. He dated the megafossils, which included *Pecten healeyi* and *Arca multicostata* var. *camuloensis*, as mid-Pliocene but did not describe the localities where they were found. As seen during the field mapping for the present report, the Miocene-Pliocene contact appeared in its rare and poor exposures to be gradational rather than unconformable.

There is some additional evidence bearing on the Miocene-Pliocene contact on Burruel Ridge, where the Pliocene beds are underlain by the upper Puente shale member. Well data show that Murdock Howell No. 1 well (section CC″, fig. 11) cored a small amount of Repetto formation at the top of the hole where the projected lower contact of the Burruel Ridge Pliocene might be expected; that Union Oil Company's Chapman 29 well (northwest end of section AA′, fig. 11) cored 650 feet of Repetto sediments; and that in Superior Oil Company's Schroeder No. 1 well (section AA′, fig. 11, southeast of Union Chapman 29) about 900 feet of Repetto sediments were penetrated. This compares with an estimated thickness of 900 feet for the Pliocene on Burruel Ridge, and does not indicate a pinchout to the southeast.

Repetto(?) Formation

The Puente formation is overlain by an arkosic marine sandstone which is doubtfully assigned to the Repetto formation of lower Pliocene age. The lower part of the Repetto(?) formation consists largely of medium- to fine-grained olive-green to light gray very micaceous sandstone, most of it poorly indurated. Cross-bedding, much slumping, and jointing make precise attitudes difficult to ascertain. The general trend of the formation is N. 65° E., the dip 20° NW.

[16] English, Op. cit., p. 42.
[17] Adams, B. C., An ecologic analysis of a Pliocene faunule from southern California: Stanford Univ. Micropaleontology Bull., vol. 3, no. 4, pp. 122-127, 1932.

In typically lower Repetto(?) exposures there is a rude interbedding of buff layers as much as a quarter of an inch in thickness with blue-gray layers as much as half an inch in thickness. Fresh-looking mica in shades of green and brown may make up to 30 percent of both layers. The interbedded material is in many places cut by joints at intervals of a few inches; these may be filled with sand in such a way as to form false bedding planes difficult to distinguish from true bedding. Around Burruel Point the sandstone tends to form low rounded hills, and on almost every hill loose cobbles and boulders are found. These may be weathered from a Repetto(?) conglomerate, but they appear to be residual, or lag deposits from a younger formation. Pebbles and cobbles are rarely found in the soil, which covers the hills to a depth of 3 or 4 feet.

About 50 feet above the base of the Repetto(?) there is in places a coarse-grained conglomerate, only 4 or 5 feet thick. It consists of subangular pebbles, cobbles, and boulders of quartzite, biotite granodiorite, and porphyritic volcanic rocks (mostly purple andesite) in a brown matrix of gritty, micaceous sandstone. In or just above the conglomerate at Burruel Point, megafossils were collected at three localities (loc. 1, 2, 3, pl. 1) approximately the same along horizon. Similar fossil fragments were collected somewhat higher in the section (loc. 4, pl. 1). Specimens in the collections were tentatively identified as follows:

Gastropods

Neverita recluslana (Deshayes)
Operculum of Astraea (Pomaulax) gradata(?)
Turritella sp.

Pelecypods

Arca multicostata Sowerby var. camuloensis Osmont
Arca trilineata Conrad var. calcarea
Lucina acutilineata Conrad
Pecten sp.

Crustacea

Balanus sp.

Flora

Salix scouleriana (a willow now living in western Washington and Oregon at 5,000-7,000′ elevation)

Some shark teeth were found. The large, thick, and heavy *Arca* shells are about equal in number to all other species combined. This fauna indicates shallow water deposition during Pliocene time.

One collection of foraminifera was made about 300 feet above the base of the Repetto(?) formation (loc. 5, pl. 1). It consisted of:

Bolivina spissa var. serrata
Cassidulina californica
Cassidulina subglobosa quadrata
Eponides subtenera
Globobulimina pacifica
Pseudoparella pacifica
Pseudoparella subperuviana
Uvigerina cf. peregrina
Uvigerina pygmea

These species range through the Pliocene, but the *Bolivina* species is especially common in the lower Pliocene in this area. Near the middle of the formation some bits of petrified wood were found and near the top a few unidentifiable casts of megafossils were observed in the field.

The highest Repetto(?) exposures may be those cropping out in the north-south road cut east of Olive where a few thin beds of well-rounded pebbles and cobbles may be seen; they were not traceable in the field.

La Habra(?) Formation

Unconformably above the Repetto(?) sandstone there is a distinctive formation consisting of conglomerate, siltstone, and sandstone. Subangular to well-rounded pebbles and cobbles in a coarse-grained matrix of orange to red arkosic sandstone form a fairly well-cemented and, in places, well-sorted conglomerate. The lithology is especially well shown in an abandoned quarry at Burruel Point just east of the north-south highway. The sandstone matrix, composing about half of the conglomerate, is made up chiefly of angular quartz grains and some feldspar and biotite. The pebbles and cobbles appear to be about half black slates, similar to those cropping out in the basement complex to the southeast, and half a mixture of light-colored aplites and quartzites; volcanic clasts are not common. One or two thin gray-green micaceous conglomeratic sandstone beds irregularly separate the conglomerates, many of which appear to be channeled into these beds. Dips of 5° to 25° in a general westerly direction were observed in thinner sandstone lenses in the conglomerate and in the conglomerate itself. Just north of the city limits of the town of Olive, the conglomerate is interbedded with a striking brick-red coarse to gritty fairly well-cemented sandstone similar to that forming the cement of the conglomerate to the east. In the north-south highway cut east of Olive there is a change upward in less than 5 feet of section, from pebble conglomerate to clayey sandstone. In the sandstone there are small fragments of weathered soft gray-white shale similar to that found in the Puente formation.

The conglomerate exposed on the hills just east of Olive is doubtfully assigned to La Habra formation of probable lower Pleistocene age. The conglomerates seem to be continental deposits. It is not certain that the overlying sandstones have a similar origin. They appear to be conformable upon the conglomerate and are considered to be of similar age.

Terrace Deposits

Terrace deposits were recognized at several levels. The lowest, a locally mappable terrace covered with fine sediments, and only a few feet above the active stream, was included with the recent alluvium in order to differentiate it from the much coarser and higher remnants of former stream deposits along the north and south slopes of Burruel Ridge. The latter deposits are of two principal types, an upper cobble deposit with an orange matrix, and a lower cross-bedded deposit of alternating silt and pebbles. All of the deposits are relatively unweathered and undeformed.

Recent Alluvium

At Burruel Point, Recent deposits consist of fine-grained, soft, very micaceous sand which exhibits rude bedding planes. Eastward, the deposits grade into a coarse sand consisting of abundant quartz grains and less abundant mica.

Igneous Rocks

At the base of the lower Puente formation along section CC′ (pl. 1) there is an outcrop of diabase, probably extru-

FIGURE 8. Gray, coarse, cross-bedded terrace gravels and pebbles along Highway 18 about 50 feet above the present bed of Santa Ana River.

sive. East and west along the same contact there are small patches of tuff, but no other occurrence of diabase was found.

A limestone vein three-quarters of an inch to 3½ inches wide cuts the diabase normal to the strike. Two similar limestone veins occur a few feet east of the measured section (table 3). One of these contains angular fragments of diabase. Apparently the limestone veins are secondary: they resemble the overlying limestone bed of the lower Puente member.

Table 3.

Lithology	Thickness in feet
Top of measured section.	
Gray-white resistant ledge-forming limestone; strike N. 65° W., dip 50° N.; overlies brown to blue siltstone bearing fish scales of Miocene age. Base of lower Puente member (?)	1.8
Pink, fine-grained, banded andesitic tuff, locally weathered to clay	0.6
Weathered purple-brown diabase. Thin section: plagioclase (An_{86}) laths as much as 3/2 mm, about 40% of rock. Augite as large as 1 mm. Vesicular; calcite amygdules surrounded by limonite. Rude spheroidal structures midway in the section are as much as 6″ in diameter. Strike N. 45° W., dip 57° N.	17.3
Hard blue-gray, medium-grained feldspathic sandstone; no baked zone or other "hot contact" phenomena observed. Massive soft, well-rounded and well-sorted sandstone underlies the hard sandstone. Section terminates at the base of friable arkosic sandstone. Strike N. 35° W., dip 37° N.	7.9
Total	27.6

About 2,500 feet east of the westernmost Pliocene—upper Puente shale contact are some slabs of hornblende-andesite of such size and angular shape as to suggest a nearby source of igneous material. The largest slab, not completely exposed, measured 5.5 by 5 by 2.5 feet. Immediately alongside lay another partially buried slab 3.5 by 5.5 by 1.5 feet. Smaller fragments lie within 100 feet along the strike, mingled with smaller boulders and cobbles of black sandstone and metamorphic rocks.

FIGURE 9. Profile of diabase outcrop at top of Topanga formation.

STRUCTURE

Folds

Burruel Ridge forms the north limb of an eroded west-plunging anticline, which has an axis south of the mapped area. This is demonstrated by the presence of a thick section of south-dipping Tertiary sediments to the south and east of Burruel Ridge.

The general strike of the sediments on Burruel Ridge is N. 75° E. and the dip, tending to steepen in the older beds, is from 15° to 65° N. A structural terrace apparently parallels the strike, as indicated by the structure sections (fig. 11). There are many minor structures which cross the major structural trend nearly at right angles. In the highway cut half a mile northeast of Olive, two symmetrical chevron folds, and to the north a small syncline, are well exposed. At least one small fault, displace-

FIGURE 10. Limestone vein cutting across diabase outcrop. Lime was apparently derived from the overlying lower Puente shale.

ment about 6 feet, is visible in the little syncline in the highway cut. These structures, too small to be shown on the map, do not seem to be present across the road to the east.

Anomalous attitudes suggesting folding were frequently encountered in the Repetto sandstone on the north dip slope near structure section AA′. Many attitudes, especially those west of section AA′, were not considered sufficiently reliable for the plotting of structures.

The small east-west anticline shown in structure section BB′ (fig. 11) was marked by comparatively well-exposed south dips to the east of the fault. The north and south dips to the west of the fault are considerably flatter.

No south dips were found to substantiate the short anticline mapped west of section CC′, but one is suggested by the small patches of pink upper Puente shale which were found beneath the Sycamore Canyon sandstone. The trace of the anticline was not continued east of the northeast-trending fault because it is believed from this point on to be subordinate to the dominant north-south structural trend which seems to prevail east of the Wagon-Wheel ranch house. Although complicated by faulting and by thinning of beds, north-trending structures may be seen in the outcrop pattern. All of the folds seem to be rather sharp and asymmetrical with a variable north plunge of perhaps 10°. The north-plunging syncline marked by the outcrop of upper Puente shale is a closed structure. The east limb of the easternmost north-plunging anticline apparently is the west limb of another sharp syncline which lies just off the map.

Faults

No major faults were found in the Burruel Ridge area but a number of minor north-trending faults have offset the generally east-west contacts. An east-striking fault may follow the Santa Ana River at the foot of the north face of the ridge, but positive evidence is lacking; a synclinal fold along the Santa Ana River valley here may fully explain differences in age and attitude of formations on the north and south sides of that valley.

Two northeast-trending faults appear to be post-Topanga but pre-Puente. One of these, shown in section CC′ near Santiago Creek, apparently left-laterally offsets the contact between the Sespe-Vaqueros and Topanga formations about 1,100 feet (map distance). Offsets in the indicated *Turritella ocoyana* bed and in a *Chione temblorensis(?)* zone are in agreement, but the Topanga-lower Puente contact appears unaffected. A mile due east a north-northeast-trending fault shows similar relationships and offset. The east side of each of these two faults is the apparently upthrown block. The diabase emplaced at the top of the Topanga formation and cropping out just west of the more westerly of these two faults may have been removed from the east block after faulting and before the lower Mohnian lower Puente shale member of the Puente formation was deposited.

The remaining faults are younger than middle Miocene. The east-trending fault south of Rubicon Wilcox No. 1 well (no. 7, pl. 1) accounts for the repeated section of upper Puente shale exposed north of it and also explains somewhat the large areal exposure of Sycamore Canyon sandstone at a point so near the first outcrop. The surface evidence for the fault consists of a small sag pond at its westernmost trace, a well-marked gouge zone just west of the line of section DD′, a rather lush growth of willow-like trees fed by an intermittent spring about 1,200 feet east of the line of section DD′, and the appearance of the upper Puente shale contact with the underlying sand near the eastern map boundary.

Just east of Richfield Oil Company's Peralta Hills No. 1 well (section BB′, fig. 11) a fault may be seen in the east-west highway cut, with younger sediments apparently exposed on the downthrown eastern side. Along its projected strike to the southeast a fault is fairly well marked in the middle Puente sandstone and lower Puente shale members of the Puente formation. Two north-trending faults in the Puente formation west of section CC′ suggest considerable downthrow on the eastern side. Although they could not be traced up section they may continue into the Repetto (?) formation.

The most persistent fault strikes west-northwest across section CC′. Possibly it is the most recent fault on Burruel Ridge. Where best exposed, the apparent displacement was estimated to be about 150 feet. The outcrop pattern of the deformed beds suggests a high-angle reverse fault.

Structure Sections

The structure sections (fig. 11) were prepared with the aid of information from oil well cores (see table 4). The sections show that there is folding or faulting near the present bed of the Santa Ana River north of Burruel Point. Section AA′ also indicates that the Puente formation becomes thicker to the north.

As shown in section EE′, the Sycamore Canyon member of the Puente formation becomes thicker to the east as the Repetto (?) formation becomes thinner. Also, at an average rate of about 400 feet per mile, the lower units (that is, the top of the lower Puente shale member of the Puente formation) occur higher in the section. These units apparently do not thicken, and the middle Puente sandstone member of the Puente formation, at least, becomes thinner.

From Wheelock Collins Abercrombie and Porter's Travis No. 1 well (no. 5, pl. 1), oriented magnetic cores were taken. These had dips ranging from 5° to 25°. The dips in the upper part of the section, from 670 to 1,495 feet from the surface, averaged 18° N. 69° W. From 1,495 to 3,150 feet (bottom of hole), the dips swung slowly southward: 5° S. 77° W. at 1,495 to 1,907 feet; 21° S. 81° W. and S. 50° W. at 2,920 to 2,930 feet; and 8° S. 16° W. at 3,000 to 3,010 feet. The higher dips and the suggested strikes are comparable to attitudes found in the Sycamore Canyon outcrops south of the Santa Ana River (that is N. 42° E. 29° NW.). The dips recorded lower in the Travis No. 1 well may be more significant as a key to structure. They show that although the pre-Sycamore Canyon beds dip gently, they also swing rather sharply to the northwest on the north side of the Santa Ana River. Oriented cores from at least one other well east of the Orange quadrangle and north of the projected line of section EE′ show a similar trend. The new direction of strike would seem to lead into the structures of the Kraemer area of the Richfield oil field, which is characterized by a west-plunging asymmetrical anticline trending about N. 70° E.[18].

[18] Reese, R. G., Kraemer area of the Richfield oil field: California Div. Mines Bull. 118, p. 361, 1943.

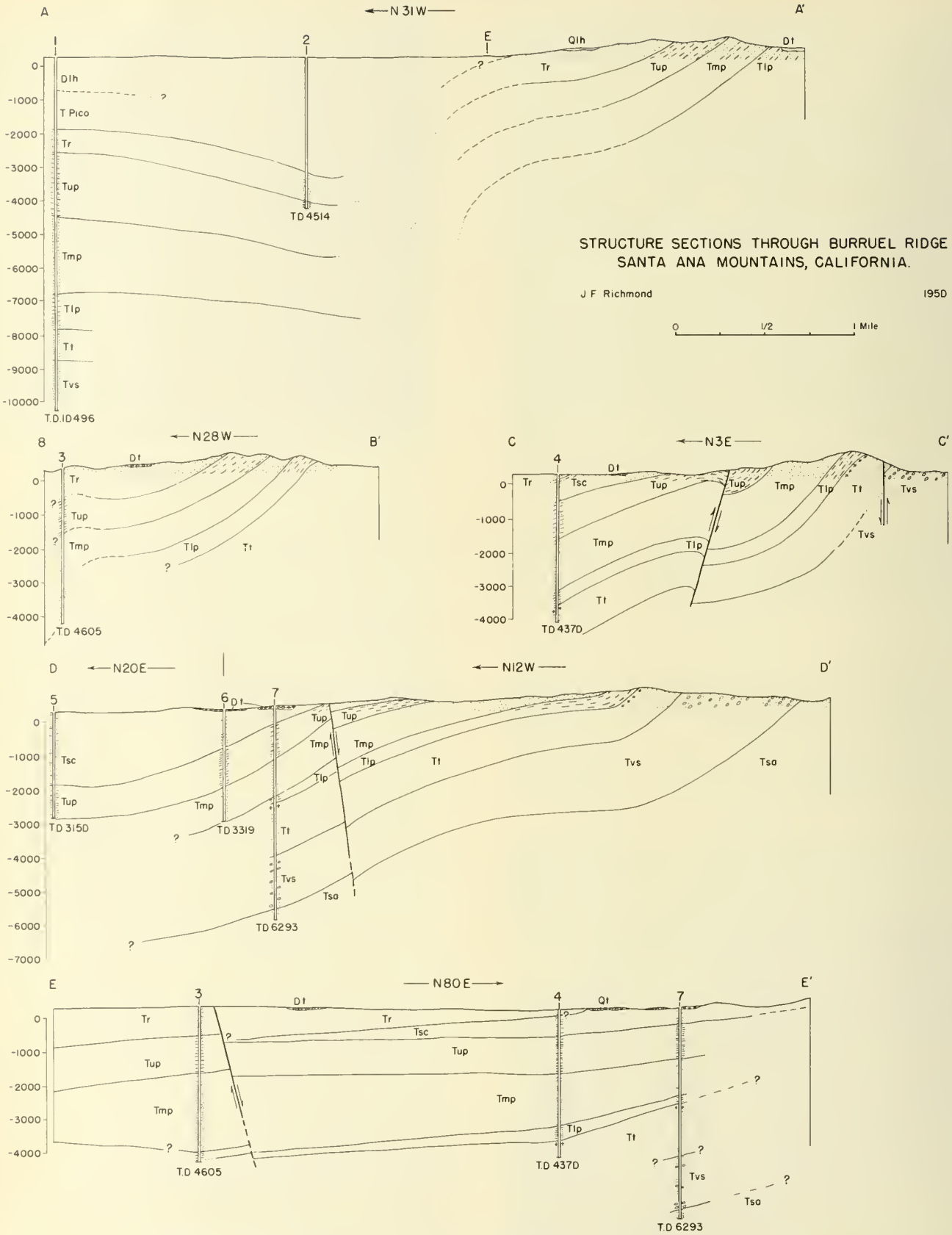

FIGURE 11. Structure sections through Burruel Ridge, Santa Ana Mountains, California.

Table 4. Data from oil-well cores.

(All dry holes except Union Chapman 29. Elevation and depth to tops of formations in feet.)

No. (pl. 1)	Company	Well name	Year begun	Elevation (feet)	Total depth (feet)	Repetto	Puente				Topanga	Remarks
							Sycamore Canyon	Upper Puente	Middle Puente	Lower Puente		
1.	Union Oil Co.	Chapman No. 29	1936	290	10,496	1,890	- - -	2,600	4,515	6,850	8,153	Bottomed in Sespe
2.	Superior Oil Co.	Schroeder No. 1	- - -	252	4,514	3,380	- - -	4,289	?	- - -	- - -	Projected 2,000′ west to Sec. AA′
3.	Richfield Oil Corp.	Peralta Hills 1	1950	400	4,605	0	- - -	880	1,980	4,320	- - -	Dips at bottom of hole about 80°
4.	Murdock, G. B.	Howell No. 1	1946	315	4,370	0?	100?	820?	1,980?	3,500	3,900	No good contact above 3,500
5.	Wheelock Collins et al.	Travis No. 1	1948	325	3,150	- - -	0	2,120	3,150	- - -	- - -	Dips in oriented cores av. about 15°-20° west
6.	Landess Oil Co.	Landess No. 1	1947	400	3,319	- - -	0	1,120	2,250		- - -	E. L. points only (no forams)
7.	Rubicon Oil Co.	Wilcox No. 1	1947	460	6,293	- - -	0	570	1,600	2,630	2,840	Sespe 4412 "Eocene" 6,293 (**Haplophragmoides** sp.)

The evidence suggests that the course of the present Santa Ana River along the northwest edge of the Santa Ana Mountains roughly follows a westward-plunging syncline. The magnitude of the syncline is of the same order as that of the large west-plunging anticline having its axis south of Burruel Ridge. The changing dips in the Wheelock Collins et al. Travis No. 1 well might indicate that formation of the syncline occurred before upper Puente formation gradually filled an already existing synclinal trough. Additional information is needed to confirm this. An eastern or northeastern source of coarse sediments during the time of deposition of the Sycamore Canyon member is indicated.

GEOMORPHOLOGY

Burruel Ridge follows the eastward trend of the larger geologic structures, which cut sharply across the north-northwest-trending Santa Ana Mountains. The north dip slope and the steeper south revet slope are the topographic expression of the eroded north limb of a large anticline.

Drainage on the north side of the ridge is controlled by the apparently antecedent Santa Ana River. The river flows about S. 80° W. in the trough of a west-plunging syncline having its axis nearly in the river channel. At the town of Olive the river swings sharply to S. 20° W. where it crosses the nose of the west-plunging anticline whose axis is south of Burruel Ridge.

Intermittent consequent streams have cut deeply into the north dip slope, forming narrow V-shaped gullies. At various levels above the present bottoms of the larger canyons drained by these small north-flowing streams, dissected remnants of old stream terraces as much as 100 feet long may be found. The highest level is about 200 feet above the bottoms of the canyons, which are at such points about 300 feet above the present Santa Ana River.

Much larger stream terraces left by the ancestral Santa Ana River are present at several levels above the present river bed. Two levels are especially well marked in the area east of section BB′ on the south side of the Santa Ana River at about 100 and 150 feet respectively above its present bed (400 and 450 feet above sea level). Deposits on the higher terrace consist chiefly of pebbles and cobbles of light-colored plutonic rocks and hard gray sandstone fairly well cemented in a matrix of coarse-grained orange sandstone. The lower terrace deposits are finer, being composed of alternating layers of fine-grained mud and coarse-grained gravels and pebbles. The matrix of the gravels is usually a soft gray sand. The lower terrace deposits are well cross bedded, in contrast to those of the upper terrace.

Flat-lying benches suggestive of even older Santa Ana River terraces are also found as remnants in the same location at higher elevations than those mentioned. No terrace material is on them now; but small patches of weathered cobbles and boulders of hard gray sandstones, alaskite, quartzite and gneissoid plutonic rocks may be found on nearly every hilltop at the western end of Burruel Ridge at elevations up to 500 feet, or more than 200 feet above present Santa Ana River terrace.

Terraces above Santiago Creek are higher than those above Santa Ana River. They commonly occur 250 and 300 feet above Santiago Creek. Several remnants of two terraces were found at 250 and 300 feet respectively above Santiago Creek (600 and 650 feet above sea level). Less-well-preserved remnants are present at 400 feet above Santiago Creek (850 feet above sea level). The terrace deposits of ancestral Santiago Creek are chiefly rounded cobbles and boulders of gneissoid biotite granodiorite, light-colored, coarse-grained plutonic rock, and volcanic rock. The percentage of matrix to cobbles is less in the Santiago Creek terrace deposits than in Santa Ana River terrace deposits; in the latter, the matrix is about 50 percent of the deposit. The composition of the matrix of the Santiago Creek deposits is similar to that of the upper Santa Ana River terrace. The matrices have in common the approximate proportions of angular quartz clasts (about 60 percent), feldspar (20 percent), and biotite (10 percent). The same rusty red color is common to both. The lower terrace deposits left by Santiago Creek are much coarser than any of those of Santa Ana River. Boulders as much as 20 inches in diameter are fairly abundant in the lower terrace materials of Santiago Creek.

The small consequent streams draining the south side of Burruel Ridge apparently represent a younger stage in the erosion cycle than do those of the north slope. The profiles of the south-flowing streams are much steeper and are marked by numerous nick points. Their cross profiles are not as well developed and the terrace remnants left by them are only a few feet above the canyon floors.

South and west of section BB′ and north of Santiago Creek, a rather large area is covered with thick, coarse, terrace deposits. These have been partially dissected and

beneath them are exposed small outcrops of older formations which were not separately mapped.

Santa Ana River terrace deposits observed in section sometimes seemed to have a slight northward tilt of about 5°. Such indications were less apparent in the Santiago Creek terrace deposits. The suggestion of northward tilting, taken with the definitely higher elevation of ancestral Santiago Creek deposits, may indicate that there has been uplift along Burruel Ridge in post-terrace time.

ECONOMIC GEOLOGY *

Oil Prospects. Waring [19] in 1914 noted that one dry hole had just been drilled, and that another oil well was being drilled, at Burruel Point; apparently it too was dry. The number of wells drilled since then is not known precisely. As indicated in table 4, four wells have been drilled in the past 4 years; but, as far as is known, no oil has been encountered.

Clay. For many years a clay deposit about half a mile east of the town of Olive has been mined.[20] Approximately 25 years ago [21] common brick, hand-made roofing tile, and floor tile were among the products manufactured at the plant which is adjacent to the clay pit. Since renewal of operations in early 1951 only sewer pipe has been produced at the plant, which is owned by B. B. Garret, Mission Clay Products Corporation, 1696 East Santiago Boulevard, Olive, Orange County. It has a maximum output of 7,500 feet of sewer pipe per week using three kilns. Two kilns are now in operation.

The local clay pit is a storage reservoir for water from the Santa Ana River which is used for irrigation. In winter the reservoir is drained and clay is mined and stored on high ground for future consumption. Claystone and siltstone are obtained from flat-lying beds of the Repetto (?) formation. About 60 percent of local clay is combined with clay from Alberhill and Corona to make a sewer-pipe mix. The latter clays are furnished by an operator named McClintock, who mines pits in both areas.

Clayey shales occur locally in both the upper and lower Puente members of the Puente formation. At foraminifera locality 479 (loc 11, pl. 1), clay is present in fairly large amounts. The quartz-free tuff cropping out on the ridge at the lower Puente shale-Topanga contact along section DD′ has weathered to a fairly fine clay.

Diatomite. East and west of line of section AA′ a deposit of white to buff diatomite at least 300 feet thick crops out for about half a mile on a dip slope, but its commercial possibilities are unknown.

* Revised to 1951.

[19] Waring, Op. cit.

[20] Dietrich, W. F., The clay resources and the ceramic industry of California: California Div. Mines Bull. 99, p. 141, 1928.

[21] Tucker, W. Burling, Orange County: California Min. Bur. Rept. 21, p. 65, 1925.

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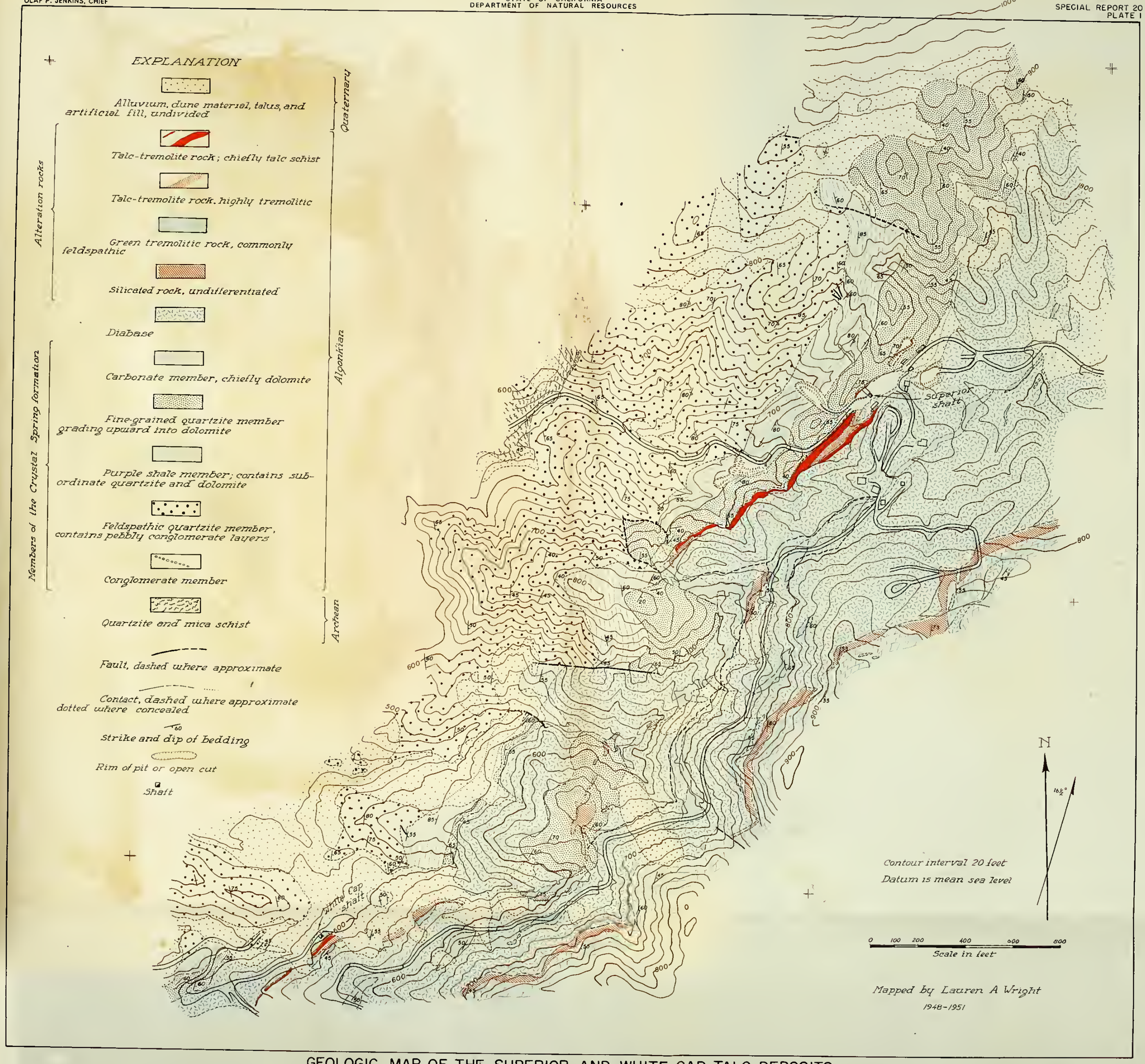
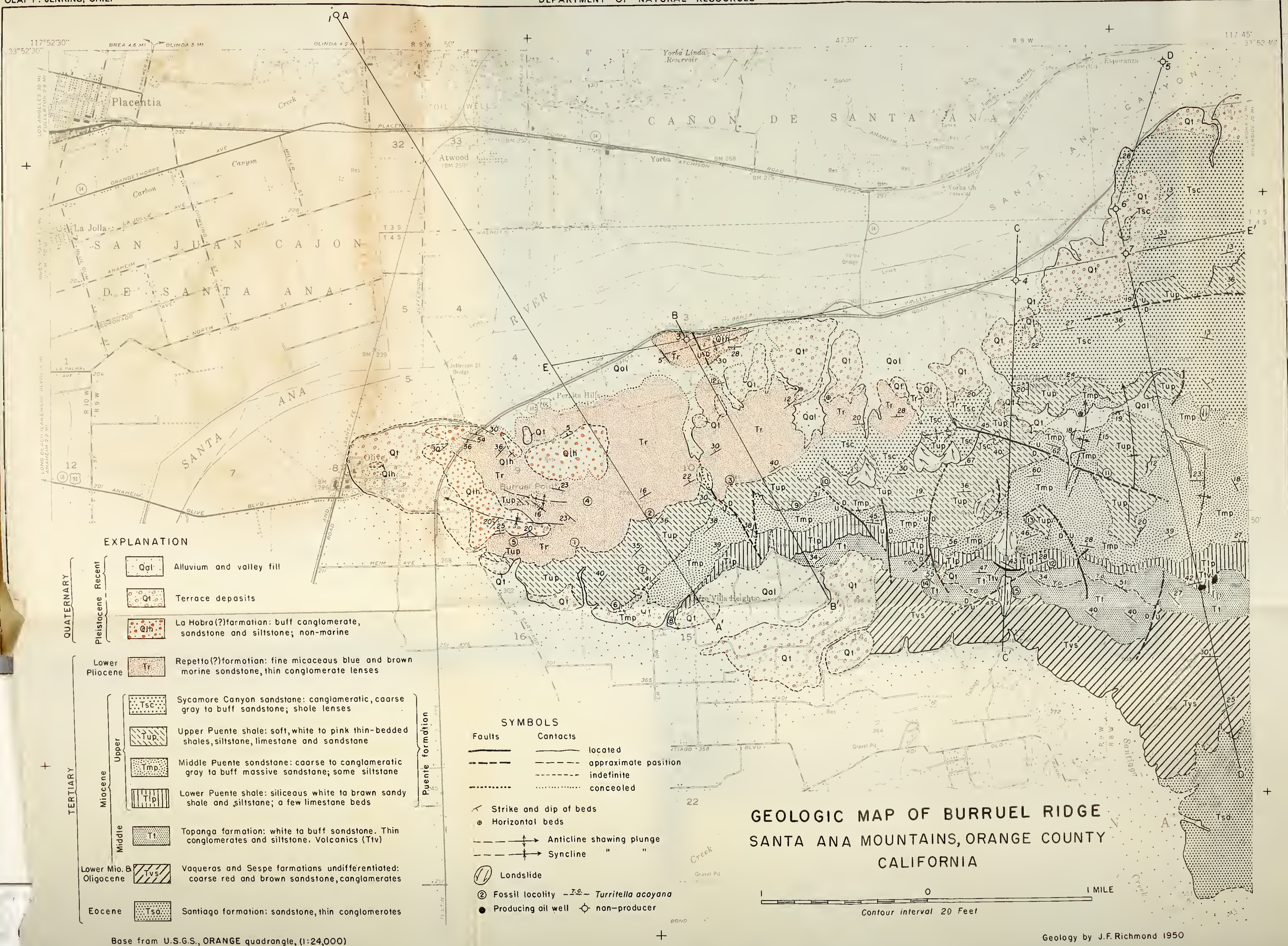


GEOLOGIC MAP OF THE SUPERIOR AND WHITE CAP TALC DEPOSITS
SAN BERNARDINO COUNTY, CALIFORNIA


GEOLOGIC MAP OF BURRUEL RIDGE
SANTA ANA MOUNTAINS, ORANGE COUNTY
CALIFORNIA
EXPLANATION
QUATERNARY
Pleistocene Recent
Qal Alluvium and valley fill
Qt Terrace deposits
Qlh La Hobra(?)formation: buff conglomerate, sandstone and siltstone; non-marine
TERTIARY
Lower Pliocene
Tr Repetto(?)formation: fine micaceous blue and brown marine sandstone, thin conglomerate lenses
Miocene
Upper
Tsc Sycamore Canyon sandstone: conglomeratic, coarse gray to buff sandstone; shale lenses
Tup Upper Puente shale: soft, white to pink thin-bedded shales, siltstone, limestone and sandstone
Tmp Middle Puente sandstone: coarse to conglomeratic gray to buff massive sandstone; some siltstone
Tlp Lower Puente shale: siliceous white to brown sandy shale and siltstone; a few limestone beds
Puente formation
Middle
Tt Topanga formation: white to buff sandstone. Thin conglomerates and siltstone. Volcanics (Ttv)
Lower Mio. & Oligocene
Tvs Vaqueros and Sespe formations undifferentiated: coarse red and brown sandstone, conglomerates
Eocene
Tsa Santiago formation: sandstone, thin conglomerates
SYMBOLS
Faults
Contacts
located
approximate position
indefinite
concealed
Strike and dip of beds
Horizontal beds
Anticline showing plunge
Syncline " "
Landslide
Fossil locality T.O. Turritella acoyana
Producing oil well
non-producer
Contour interval 20 Feet
1 0 1 MILE
Base from U.S.G.S., ORANGE quadrangle, (1:24,000)
Geology by J.F. Richmond 1950
Placentia
Atwood
Yorba Linda Reservoir
CAÑON DE SANTA ANA
SAN JUAN CAJON DE SANTA ANA
SANTA ANA RIVER
SANTA ANA CANYON
Olive
Burruel Point
Villa Heights
Santiago
Tsa